SUBSTITUTE SPECIFICATION

TITLE: OPTICAL DISC DRIVE, AND METHOD FOR OPERATING AN OPTICAL DISC DRIVE

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BACKGROUND OF THE INVENTION

Field Of The Invention

[0001] The present invention relates in general to the field of optical storage, more particularly, a device for reading or writing information from (or to) an optical storage medium, especially an optical disc. As is commonly known, such apparatus comprises a motor for rotating the disc, and a laser device for generating a laser beam scanning the surface of the rotating disc.

[0002] During operation, the temperature of the device rises. If the temperature of the laser device becomes too high, the lifetime of the laser device decreases. Therefore, it is desirable to limit the temperature of the laser device.

Description Of The Related Art

[0003] Thus, an optical disc drive is provided with temperature controlling means which is effective to cool down the laser device, for instance, by setting the rotational speed of the disc drive motor to a lower value. This temperature controlling means needs a sensing means for sensing the temperature of the laser device. Japanese Patent Application 10-117506, Publication No. 11-312361, describes an optical disc drive wherein the temperature of the interior of the disc drive housing is measured by a separate temperature sensor.

[0004] One disadvantage of this known design is the need of having a separate temperature sensor. A further disadvantage is

that such a separate temperature sensor does not measure the actual temperature of the laser device itself.

SUMMARY OF THE INVENTION

[0005] An object of the present invention is to provide an optical disc drive which is capable of accurately controlling the temperature of the laser device, but which has a simpler design which does not need a separate temperature sensor.

[0006] The present invention is based on the understanding that a direct relationship exists between the threshold voltage of the laser device, on the one hand, and the temperature thereof, on the other hand. Thus, based on this understanding, the present invention proposes to take temperature controlling steps on the basis of at least one signal which is representative of, or depending on, the threshold voltage of the laser device.

[0007] In a specific embodiment, the light output of the laser device is maintained at a constant level during normal operation. The electrical parameters, such as voltage and current, of the electrical power input to the laser device, necessary to maintain the light output of the laser device at said constant level, depend on the actual value of the threshold voltage of the laser device. Thus, these electrical parameters are taken to represent the temperature of the laser device, and temperature controlling steps are taken when the value of at least one of these electrical parameters exceeds a predetermined level.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] These and other aspects, features and advantages of the present invention will be further explained by the following description of a preferred embodiment of the present invention with reference to the drawings, in which same reference numerals indicate same or similar parts, and in which:

[0009] Fig. 1 schematically illustrates an optical disc drive device;

[0010] Fig. 2 schematically illustrates a semi-conductor laser;

[0011] Fig. 3 schematically illustrates a current/voltage characteristic of a semi-conductor laser;

[0012] Fig. 4 is a flow diagram schematically illustrating the operation of temperature control in accordance with the present invention;

[0013] Fig. 5 schematically illustrates two semi-conductor lasers being controlled by a common control unit; and

[0014] Fig. 6 is a flowchart showing the steps of the inventive method for operating a disc drive.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] Fig. 1 schematically illustrates an optical disc drive device, generally indicated at reference numeral 1. The disc drive 1 comprises means for receiving an optical disc 10, the receiving means not being shown for the sake of simplicity. The disc drive 1 further comprises an electric motor 2 for rotating the disc 10, and a laser device 3 for generating a laser beam 4 directed towards a main surface of the disc 10 and scanning this main surface of the optical disc 10 as the disc rotates. The disc drive 1 further

comprises a control unit 5 controlling, on the one hand, the operation of the laser device 3, and controlling, on the other hand, the operation of the motor 2. During operation, the motor 2 is controlled to drive the optical disc 10 with a certain predetermined rotational speed.

[0016] Typically, these components are arranged within a housing 100. During operation, the temperature in the interior of the housing 100 rises. One of the causes of such a temperature rise is the fact that the motor 2 dissipates heat. The amount of heat dissipation is especially a problem at relatively high rotational speeds, such as, in the order of 200 Hz.

[0017] Fig. 2 schematically illustrates an essential component of the laser device 3. The laser device 3 comprises a semi-conductor laser component 20, comprising a P-region 21, an N-region 22, and a PN-junction 23 in between. The laser device 3 further comprises input terminals 24 for receiving an input voltage V_{in} and applying this input voltage over the PN-junction 23. The semi-conductor laser 20 generates laser light L_{out} from its PN-junction 23 if an appropriate input voltage V_{in} is applied over said PN-junction 23. Since semi-conductor lasers are commonly known, the operation of such semi-conductor laser 20 will not be explained here in more detail.

[0018] Fig. 3 schematically illustrates a current/voltage characteristic 26 of a semi-conductor laser 20. The horizontal axis represents the voltage over the PN-junction 23, while the vertical axis represents the current through the PN-junction 23.

[0019] As can be seen from Fig. 3, the semi-conductor laser 20 behaves as a diode: when the voltage is increased from zero,

initially virtually no current will flow. Only if the voltage exceeds a certain voltage threshold V_T, the current increases exponentially. This threshold voltage V_T depends on the actual temperature of the PN-junction 23. Based on this recognition, the present invention proposes to use this threshold voltage V_T, which can be determined quite accurately, as a parameter representing the temperature of the PN-junction 23.

[0020] One option is to actually measure the threshold voltage V_T. However, according to a further elaboration of the invention, this is not necessary. It is easier to measure the electrical parameters of the power input into the semi-conductor laser 20 while keeping the light output L_{out} substantially constant, because it has been found that these parameters depend on the threshold voltage V_T, and hence, depend on the temperature, as will be explained hereinafter.

[0021] The intensity of the light L_{out} generated by the semi-conductor laser 20 is substantially proportional to the electrical power input into the semi-conductor laser 20, i.e., the voltage V_{in} over the PN-junction 23 multiplied by the current I through the PN-junction 23. In Fig. 3, a curve 27 represents the points $V_{in} \cdot I$ = constant (corresponding to L_{out} = constant), the curve 27 intersecting the laser current/voltage characteristic 26 at a work point W. When the threshold voltage V_T changes, the laser characteristic 26 shifts, and hence, a new work point is set when the light intensity L_{out} is kept constant. In other words, when the temperature changes, the work point W shifts along the curve 27. Thus, the location of the work point is representative of the temperature. According to the invention, the location of the work

point is monitored and, if this location represents a temperature which is considered too high, appropriate temperature reducing steps are taken.

[0022] In a practical embodiment, the control unit 5 has an output 6 for supplying a control voltage V_{CL} as an input voltage V_{in} to an input 24 of the semi-conductor laser 20. Further, since it is desirable in the disc drive 1 to maintain the intensity of the laser beam 4 as constant as possible, the disc drive 1 further comprises a light detector 7 arranged to sense the intensity of the laser beam 4 and to generate a detector signal S which is representative of the measured light intensity and which is supplied as an input signal to an input 8 of the control unit 5. Thus, the combination of semi-conductor laser 20 and light detector 7 defines a feedback loop for the control unit 5 as regards its output control signal V_{CL} at its output 6. The control unit 5 is designed to generate its output signal V_{CL} such that the light intensity of the laser beam 4, as signaled by the input signal S at control unit input 8, remains constant. Then, in view of the temperature dependency of the threshold voltage V_T of the semi-conductor laser 20, the electrical parameters V_{CL} and I at the output 6 of the control unit 5, being the "coordinates" of the work point W, constitute a direct measure of the temperature of the PN-junction 23. In the following, although the control unit 5 may monitor said electrical parameters V_{CL} and I separately, it will be assumed that the control unit 5 monitors the location of the work point W.

[0023] Thus, in principle, it would be possible for the control unit 5 to measure the actual temperature of the PN-junction 23

quite accurately. However, such is not necessary for controlling the temperature of the laser device 3. It is sufficient if the control unit 5 is designed to take appropriate action as soon as it finds that the temperature of the laser device 3 reaches a critical temperature value T_{CRIT}. Normally, this predetermined value T_{CRIT} is defined by a manufacturer of the semi-conductor laser device 3. Since the relationship between electrical parameters at output 6 of control unit 5 (i.e., location of work point W), on the one hand, and PN-junction 23 temperature, on the other hand, is a fixed relationship, the critical temperature T_{CRIT} corresponds to a critical work point W_{CRIT}. Thus, the control unit 5 can be designed to take appropriate action when the work point W reaches a predetermined critical work point W_{CRIT}.

[0024] Fig. 6 shows a flowchart illustrating the operation of the control unit 5. From a start 60, the control unit 5, at step 61, generates the laser control voltage V_{CL}. At step 62, the control unit 5 applies the laser control voltage V_{CL} to the semi-conductor laser device 3. At step 63, the control unit 5, using the light detector 6, detect the light intensity L of the light beam from the semi-conductor laser device 3. At step 64, the control unit 5 determines whether the detected light output L is constant. If not, at step 65, the control unit 5 determines if the light output has increased. If not, at step 66 the control unit 5 increases V_{CL} and the method reverts to step 62. If the light output has increased, at step 67, the control unit 5 decreases V_{CL} and the method reverts to step 62.

[0025] Contemporaneous with the step 63, at step 68, the control unit 5 measures the electrical parameter(s) applied to the semi-

conductor laser device 3. At step 69, the control unit 5 determines the temperature T using the measured electrical parameter(s). At step 70, the control unit 5 determines whether the temperature T is equal to or greater than the critical temperature T_{CRIT}. If so, at step 71, the control unit 5 institutes temperature reducing steps, and exits at step 72. Alternatively, if, at step 70, the temperature T is less than the critical temperature T_{CRIT}, the method reverts back to step 68.

[0026] As will be clear to a person skilled in the art, the critical work point W_{CRIT} will have critical coordinates V_{CRIT} and I_{CRIT}. Thus, the control unit 5 may be designed to monitor its output voltage V_{CL} and its output current I and, while keeping the light intensity of the laser beam constant, to take appropriate action when either one of its output voltage V_{CL} and its output current I reaches the corresponding critical values V_{CRIT} and I_{CRIT}, respectively.

[0027] Said appropriate temperature decreasing action can, for instance, be: completely switching off the laser device 3; activating a separate cooling unit (not shown); or controlling the motor 2 such that the rotational speed of the motor is reduced. In the latter case, the motor will dissipate less heat, causing the laser device 3 to cool down.

[0028] The control unit 5 is further designed to return to normal operating mode when the temperature of the PN-junction 23 has dropped to a sufficiently low level, such as indicated by the work point reaching a second location W_{NORM}.

[0029] Fig. 4 is a flow diagram schematically illustrating the decisions made by the control unit 5 according to a preferred

embodiment of the present invention. In the following explanation, for the sake of simplicity, it is assumed that the control unit only monitors its output voltage. However, as mentioned above, the control unit will in fact also monitor its output current.

[0030] Following the starting of the disc drive 1 at step 51, the control unit 5 enters a first operative mode wherein the control unit 5 generates a motor control signal C_m for the motor 2 in order to rotate the motor at a first rotational speed, as indicated by step 52. This first rotational speed is a relatively high speed, typically higher than 100 Hz, and, for instance, in the order of 200 Hz.

[0031] In the first operative mode, the control unit 5 is designed to continuously monitor its output voltage V_{CL} at its output 6, and to compare this output voltage V_{CL} with a predetermined critical voltage V_{CRIT}, as indicated by step 53. As long as its output voltage V_{CL} is higher than said predetermined critical voltage V_{CRIT}, the control unit 5 remains in the first operative mode, i.e., it continues to supply the motor 2 with the motor control signal C_m in order to rotate the motor at the first speed, indicated by step 52.

[0032] If the temperature of the PN-junction 23 rises, the threshold voltage V_T of the PN-junction 23 decreases. This means that the work point W shifts to the left (Fig. 3), and the same light intensity is produced by the semi-conductor laser 20 at a lower voltage over the PN-junction 23 and a correspondingly higher current. Thus, during operation, the output voltage V_{CL} of the control unit 5 will decrease. As soon as the control unit 5 finds that its output voltage V_{CL} is equal to or even lower than the

predetermined critical voltage V_{CRIT}, the control unit 5 enters a second operative mode in which the temperature of the PN-junction 23 is forced to drop. This second operative mode is indicated as step 54 in Fig. 4. As mentioned above, this second operative mode may involve the actuation of a cooling device, or switching off the laser 3. However, in this preferred embodiment of the invention, the second operative mode of step 54 involves the generation of a motor control signal C_m such that the motor 2 is rotated at a second rotational speed lower than the above-mentioned first rotational speed. In this manner, the motor 2 will generate less heat and, since the motor 2 is the main source of heat generated within the housing 100, the PN-junction 23 of the laser device 3 will gradually cool down.

[0033] Even in this second operative mode, the control unit 5 is designed to continuously monitor its output voltage V_{CL}, now comparing it with a second threshold voltage level V_{NORM}, as indicated by step 55. As long as its output voltage V_{CL} is lower than said second threshold voltage level V_{NORM}, the control unit 5 remains in the second operative mode, i.e., it continues to supply the motor 2 with the motor control signal C_m in order to rotate the motor at the second speed, indicated by step 54.

[0034] When cooling down, the threshold voltage V_T of the PN-junction 23 rises, causing the output voltage V_{CL} of the control unit 5 to rise as well. As soon as the control unit 5 finds, in step 55, that its output voltage V_{CL} has reached the second threshold voltage level V_{NORM}, the control unit 5 is designed to move from the second operative mode back to the first operative

mode, indicated at step 52, such that the rotational speed of the motor is increased.

[0035] In a particular embodiment, a disc drive may comprise two or more semi-conductor lasers 20, for generating a plurality of laser beams 4. This situation, which, for instance, applies in the case of a DVD player, is schematically illustrated in Fig. 5, where two semi-conductor lasers 20A and 20B are controlled by a common control unit 5 having corresponding outputs 6A and 6B which supply corresponding control signals $V_{CL,A}$ and $V_{CL,B}$. Respective intensities of respective laser beams 4A and 4B are measured by respective light detectors 7A and 7B, which supply feedback measuring signals S_A and S_B to respective inputs 8A and 8B of the common control unit 5. In this case, the control unit 5 is designed to monitor two work points W_A and W_B, for instance by comparing each output voltage at each output 6A, 6B with a corresponding critical voltage $V_{CRIT,A}$ and $V_{CRIT,B}$, respectively, keeping in mind that these two critical voltages $V_{CRIT,A}$ and $V_{CRIT,B}$ need not necessarily be identical to each other. Further, the control unit 5 is, in this embodiment, designed to enter its second operative mode with reduced motor speed if at least one of its output voltages $V_{CL,A}$ or $V_{CL,B}$ reaches the corresponding critical voltage $V_{CRIT,A}$ or $V_{CRIT,B}$, respectively. In the second operative mode, the control unit 5 is designed to compare its output voltages $V_{CL,A}$ and $V_{CL,B}$ with corresponding second voltage threshold levels $V_{NORM,A}$ and $V_{NORM,B}$, respectively, and to return to the first operative mode if all output voltages have reached the corresponding second threshold levels $V_{NORM,A}$ and $V_{NORM,B}$.

[0036] However, in a practical situation, the two (or more) semi-conductor laser devices 20A and 20B may be arranged close to each other, such that their temperatures will virtually be the same, or at least the temperature of one semi-conductor laser may be a good indication of the temperature of the other semi-conductor laser. Thus, in those cases, it suffices if the control unit 5 bases its decision (in step 53) whether or not to move from the first operative mode of step 52 to the second operative mode of step 54, and its decision (in step 55) whether or not to move from its second operative mode of step 54 to its first operative mode of step 52, only on the basis of the comparison of one output voltage with a corresponding critical voltage or a corresponding normal voltage, respectively.

[0037] It should be clear to a person skilled in the art that the present invention is not limited to the exemplary embodiments discussed above, but that various variations and modifications are possible within the protective scope of the invention as defined in the appending claims. Primarily, it should be clear to a person skilled in the art that while, in the exemplary embodiments, the work point (W) is monitored, the work point (W) is indicative of the laser's threshold voltage (V_T), which is affected by temperature changes.

[0038] For instance, in the above, it is assumed that the control unit 5 itself performs the steps 53 and 55. However, it is possible that some external unit monitors the output voltage(s) of control unit 5, performs the steps 53 and 55, and sends a command signal to the control unit to force the control unit to the first or the second operational mode.

[0039] Further, in the above it is explained that the actual value V_{CL} of the laser input voltage is compared with a certain threshold value. In a preferred embodiment, the laser input voltage is measured at a certain normal temperature, for instance room temperature or normal operating temperature; this measured laser input voltage is taken as zero value V0. Then, during operation, the voltage difference ΔV between the actual value V_{CL} of the laser input voltage and said zero value V_0 ($\Delta V = V_{CL} - V_0$) is taken as indicative for the temperature difference ΔT between the actual temperature and said normal temperature. Thus, during operation, the voltage difference ΔV is compared with a certain threshold to make the decisions of steps 53 and 55.